J5.8 WANDA: HRD'S REAL-TIME TROPICAL CYCLONE 'WIND ANALYSIS DISTRIBUTED APPLICATION'

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1. **INTRODUCTION**

The National Oceanic and Atmospheric Administration's (NOAA) Hurricane Research Division (HRD) has been producing real time analyses of tropical cyclone surface wind observations on an experimental basis since 1993 (Burpee, 1994). HRD's analyses, as described by Powell, et. al. (Powell, 1997), are created by compiling all available observations relative to the storm center about which the analysis is made. Some of these observations are taken from Air Force and NOAA aircraft, ships, buoys, Coastal Marine Automated Network (CMAN) platforms and surface airways (airports). Before going through a quality control session the observations are adjusted to simulate the same observations at a common height (10 meters), exposure (marine or land), and averaging period (maximum sustained 1 minute wind speed). Because several hours of observations are usually required to provide sufficient data for an analysis, the resulting objective analysis represents the mean state of the storm during the chosen time period. A typical 10 hour reconnaissance mission will yield two to three analyses.

The primary product of an analysis, a streamline and isotach contour plot, is designed to aid meteorologists in forecasting a storm's behavior by helping them determine the storm's current intensity and the extent of its damaging winds. During a storm's landfall, an analysis image coupled with the affected geography can help determine which areas are suffering from the most violent winds and storm surge. These tools should supply emergency managers with enough information to help limit confusion and maximize the efficiency of early search, rescue and recovery efforts in these hard hit areas. Many research and commercially oriented groups have also expressed interest in obtaining access to hurricane wind field data in flat file and graphical format.

2. **EXISTING SYSTEM**

WANDA (Wind Analysis Distributed Application), whose initial implementation saw extended use during the 1996 hurricane season, is an Object Oriented (OO), workstation based, software product that partially automates the wind analysis process discussed above (Powell, 1997). Currently, the application fetches data, wind observations and a storm track, from a repository of flat files. The repository is populated through several cron activated UNIX scripts that retrieve near real time data from the National Center for Environmental Prediction (NCEP) via the National Hurricane Center (NHC) at the Florida International University (FIU) campus during a storm via HRD's dedicated network connection. The data are then processed, quality controlled, passed on to the analysis server, and then displayed on a workstation screen as graphical products that are sent as hard copies to NHC's hurricane specialists or other clients.

Three subsystems are employed to automate an analysis: 1) Quality Control, 2) Analysis Automation and 3) Output Generation. A subsystem, in OO terms, groups tightly coupled classes of objects, such as those whose object instances frequently interact with each other, together so that the classes can be viewed as a single entity (Yourdon, 1994). Because WANDA can be naturally divided into these subsystems, it is easy to examine each separately.

2.1 *QUALITY CONTROL*

In the Quality Control subsystem, the goal is to arrive at a plot window containing observations, a storm track and geography, so that decisions can be made about the validity of the potential analysis set (Fig 1). A user may choose a synoptic (earth relative) or storm relative view of the data. The synoptic view helps the user study large scale weather systems at a particular time; it does not include a storm track. The storm relative view converts observations to a range and bearing relative to the storm over a period of time. Geography is then positioned relative to the storm at a chosen time. The storm relative view helps fill areas that are devoid of data by including all data during a period of time when the storm is considered to be near steady state. In the plot window, observations are represented as graphic representations of wind speed and direction called wind barbs. The user is provided with zooming, distance and data inspection tools to facilitate the task of selecting an acceptable set of data from the plot window.

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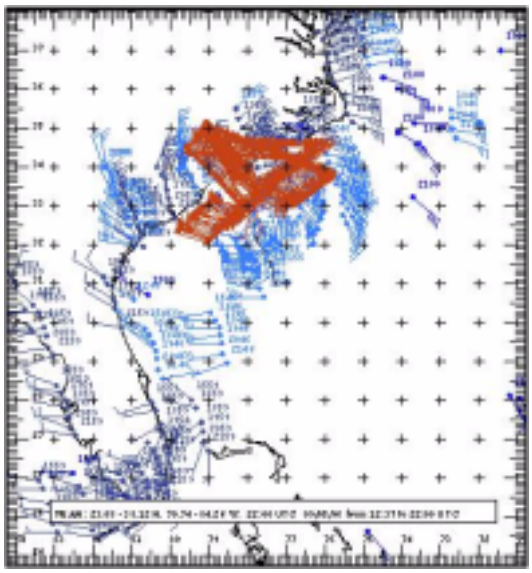

Figure 1. Quality Control plot window in a storm relative view for Hurricane Fran near landfall in 1996.

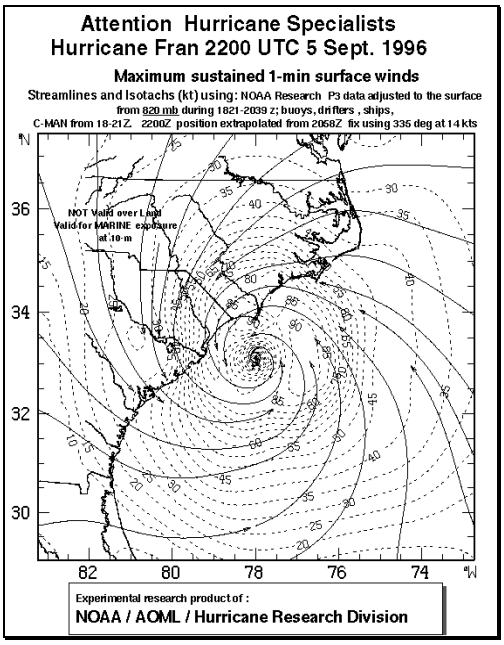

Figure 2. Primary analysis product. Streamlines and isotach contour plot.

2.2 *ANALYSIS AUTOMATION*

Once the data pass quality control, they are passed, along with a storm track, through a series of Analysis Automation subsystem components. Each component is distributed over two machines, a NextStep client and a VAX/VMS server where the analysis programs reside. WANDA uses state machines to orchestrate all of the transitions involved in analysis automation. Included in this automation is the archival of all steps of an analysis for research purposes. Through these archives, any analysis can be traced back to its components' results and intermediate data sets. The state machines also report errors and handle interruptions due to errors by popping states off a "state stack" once a failure is encountered. This way a component can only be completed and move to the next component if no errors are encountered. The use of state machines also makes maintenance much easier in that errors are accurately reported and changes in functionality often only involve changing the machine to address the new needs.

2.3 *OUTPUT GENERATION*

The Output Generation subsystem creates the graphical representation of the wind fields as discussed earlier (Fig. 2). This subsystem currently relies on an in house graphics package to display an analysis result (streamlines and isotach contours) on the client workstation screen where a meteorologist can then annotate it and save it to an encapsulated postscript document. The document can then be delivered to NHC forecasters for use as guidance in preparing hurricane and tropical storm warnings and advisories. Analyses are also archived for research purposes and for distribution on the world wide web. For example, an archived analysis may be accessed, sampled at some grid interval and written to a specific GIS (Geographic Information System) file format. A specific area's emergency management team can then overlay these data over their local geography and make damage assessments or emergency decisions regarding the local population base.

Although very useful, the current system has some inherent limitations. Firstly, WANDA's use of flat file data archives marries the application to a specific filesystem and, at the same time, raises data integrity and security issues. For example, under UNIX, a developer must take measures to set the correct file protection modes on any archived data, and a separate group for WANDA's users is necessary for minimal archive data security. Secondly, lack of portability, an inherent limitation in most compiled applications, is amplified in WANDA's case through the use of code specific to the NextStep environment. A third limitation lies in the method of distribution of the analysis processes. A more robust method than using ftp, rsh, rcp and VMS DCL script can and should be used.

3. **PROPOSED SYSTEM**

A reworked WANDA product will manifest substantial improvements during the 1998 Hurricane Season. Included in these improvements and additions are:

1. The use of a database management system instead of a hierarchy of flat files for all data used throughout the scope of the project. HRD is currently investigating off-the-shelf Object Oriented and Object Relational databases to meet these ends. A database schema for WANDA's data

already exists and is the subject of a Master's Thesis at Florida International University (Morisseau-Leroy, 1997). Two databases, one at AOML and one at NHC, will be used for redundancy in case of a landfall in the South Florida area or during periods of heavy use or inevitable outages.

2. Platform independence and client side deployment on both workstations and the World Wide Web. An implementation featuring primarily Sun Microsystems' Java programming language is possible because its "write once, run anywhere" strategy lends itself to the simultaneous development and maintenance of workstation and web versions. With Java, the WANDA application, or suite of applications, needs to be written only once and run either as an application for the workstation version or as an HTML-embedded applet for the web version.

3. The use of Distributed Object (DO) technology in the Analysis Automation subsystem. Because of the extensive meteorological expertise and time needed to port the analysis components to an OO programming language (OOPL), the current FORTRAN code will most likely be wrapped in an OOPL and distributed. HRD is currently investigating several DO options and will most likely side with a product that supports CORBA (Common Object Request Broker Architecture), IDL (Interface Definition Language) and IIOP (Internet Inter-Orb Protocol). A Master's Thesis addressing object distribution in WANDA is currently being proposed at Florida International University. Redundant analysis servers will also be made available.

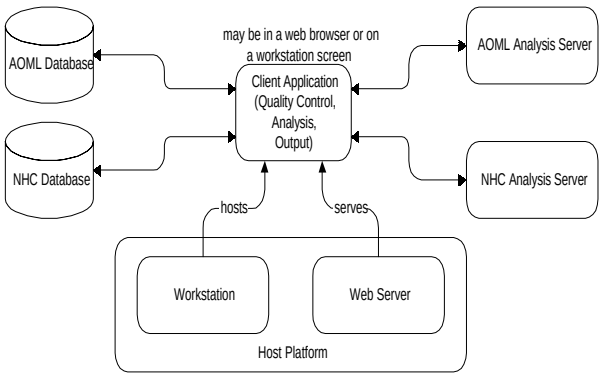

Figure 3. A generalized view of the proposed WANDA project. Redundant databases and analysis servers will be used and the application will run on both the web and on client workstations.

4. **References**

Burpee, R.W., Aberson, S. D., Black, P. G., DeMaria, M., Franklin, J. L., Griffin, J. S., Houston, S. H., Kaplan, J., Lord, S. J., Marks, Jr. F. D., Powell, M. D., and Willoughby, H. E., 1994: Real-time guidance provided by NOAA's Hurricane Research Division to forecasters during Emily of 1993. Bulletin of the American Meteorological Society., 75, 1765-1783.

Powell, M. D., Houston, S. H., Amat, Jr., L. R., and Morisseau-Leroy, N., 1997: The HRD Real-time Hurricane Wind Analysis System. 8th US National Conference on Wind Engineering Conference Proceedings, 1997.

Yourdon, E., *Object-Oriented Systems Design: An Integrated Approach*, Prentice-Hall, Englewood Cliffs, NJ, 1994.

Morisseau-Leroy, N., Atmospheric Observations, Analyses, and the World Wide Web Using a Semantic Database, Master Thesis, School of Computer Sciences, Florida International University, Miami, FL, 1997.